Datsun camshafts & Valve Timing by Racer Brown

Chapter Three

Where is the piston and what is it doing?

With the relationship of valve events and the piston positions of top and bottom centre pretty well established, let's take a look at the piston between these two positions to get a clearer picture of what going on. At any given engine speed, the angular rotation of the crankshaft, and therefore of the crankpin, is constant. However, the motion of the piston is not constant, simply because it stops twice and changes direction twice during each revolution; once at TC and again at BC, even though the crankshaft continues to rotate at a constant speed. An erroneous belief would have us swallow the idea that at points of crankshaft rotation exactly 90 degrees before and after TC the piston has completed exactly S its total stroke. No way. This could only happen if the stroke length were infinitely short and the centre-to-centre length of the connecting rod were infinitely long. But we are dealing with finite numbers here, so this idea goes in the trashcan. The piston actually travels more than S the total stroke from exact TC to a crank angle position of 90 degrees after TC. This being true (and it is, there being a number of complex equations to prove the point), piston speed is faster during the first 90 degrees of crank rotation than it is during the second 90 degrees of crank rotation because the piston can only move from exact TC to exact BC in exactly 180 degrees of crank rotation, no more, no less. From this, it can be seen that maximum piston velocity is reached at some point before 90 degrees of crank rotation from TC. This occurs when the axes of the crankshaft, crankpin and piston pin form an angle of exactly 90 degrees. This shows the relationship of the centre-to-centre length of the connecting rod and the radius of the crankpin from the crankshaft axis (exactly S the total piston stroke). The equation is: Rod length divided by crankpin radius is equal to the tangent of the angle at which maximum piston velocity is reached.
A simplified diagram is shown for the two basic engine configurations under discussion. Piston pin offset has been omitted for clarity. In the Datsun L-16/L-24 versions, maximum piston velocity occurs at 74 degrees, 31 minutes of crank rotation after TC. From TC until this point is reached, the piston is accelerating. From this point until BC is reached, which requires 105 degrees, 29 minutes of crankshaft rotation, the piston is decelerating. This holds true for both the power and induction strokes. From BC until maximum piston velocity is reached in 105 degrees, 29 minutes of crank rotation on both exhaust and compression strokes. The piston is accelerating again. From the point of maximum piston velocity, the crank rotates 74 degrees, 31 minutes for the piston to reach TC, during which time the piston is decelerating. Corresponding crank angles for the Datsun L-18 are 73 degrees, 21 minutes and 106 degrees, 39 minutes. Not much difference between the two, but enough to make a considerable difference in functional characteristics, as will be shown later. The alternate but unequal periods of piston acceleration/deceleration exert some powerful influences in optimum valve timing events for specific applications.

EXAMPLE 1: The exhaust valve reaches full lift at about the same time the piston reaches it maximum rate of acceleration on the exhaust stroke to minimise pumping losses.
EXAMPLE 2: The intake valve should open at a point about where the

piston is at is maximum rate of deceleration during the exhaust stroke to prevent serious air/fuel charge dilution as the forefront of the mixture charge attempts to enter the cylinder.
EXAMPLE 3: The intake valve should be closed before the piston reaches its maximum rate of acceleration on the compression stroke to minimise pressure-reversal disturbances generated by the piston. (There are enough disturbances going on in the engine at sonic velocities, so we don't need another one, but more about that later.)

The point here is that the piston behaves in exactly the same manner as it moves from BC to TC during the exhaust stroke and the compression stroke, in relation to maximum acceleration, maximum rate of acceleration, maximum velocity, maximum deceleration, maximum rate of deceleration, etc. Only the strokes have been changed. Therefore, the three valve events that occur during the upstroke of the piston must be pretty carefully tailored, keeping in mind where the piston is and what it is doing, for optimum results. In order of importance, intake valve opening point second, with maximum lift point of the exhaust valve a poor third because of inherently more latitude.
On the down-stroke of the piston, from TC to BC of both the power and induction strokes, the piston again behaves in exactly the same manner related to acceleration/velocity/deceleration, but it is NOT - repeat NOT - the same as on the upstroke. Look at the diagram. Three valve events also occur during two piston down-strokes.
EXAMPLE 4: Exhaust valve opens during the period of piston deceleration on the power stroke, when most of the energy of the power stroke has been converted to useful work, but when the cylinder pressure is still considerably higher than atmospheric. This allows the remaining cylinder pressure to unload itself past the exhaust valve so that when the piston reaches BC, residual cylinder pressure is only slightly above atmospheric, which of course, reduces the pumping loss when the piston begins the exhaust stroke.
EXAMPLE 5: Exhaust valve closes during the period of piston acceleration on the induction stroke, before the piston reaches its maximum rate of acceleration to prevent the escape of excess air/fuel mixture past the exhaust valve and also to prevent air/fuel charge dilution by drawing the tag end of the exhaust gases back into the cylinder as the cylinder pressure condition changes from a pressure vessel to a vacuum vessel.
EXAMPLE 6: Intake valve reaches full lift during the period of piston deceleration but before it reaches its maximum rate of deceleration. Thus the intake valve "lags" behind the piston somewhat to generate as much of a pressure differential between the cylinder and the atmosphere, for as long a period of crank rotation as practicable to impart high rates of velocity and inertia to the entering air/fuel charge, so the velocity and inertia can be utilised as a cylinder-filling expedient well after the piston has started the compression stroke. Maximum lift point of the intake valve is therefore somewhat more critical than maximum lift point of the exhaust valve.
The six valve events within four strokes of the piston, or two revolutions of the crank, which ever occurs first (You dummy! They both occur at exactly the same time!), listed in order of importance and significance to engine operation are:
1. Intake valve closing point, by far;
2. Intake valve opening point (probable);
3. Exhaust valve closing point (probable; could be reversed with (2)) under certain conditions);
4. Exhaust valve opening point;
5. Maximum lift point of intake valve;
6. Maximum lift point of exhaust valve.
The mechanical, physical, chemical actions and reactions, forces and

counterforces at work within a four-stroke cycle engine are known and recognised to be exceedingly complex and inextricably interrelated. Today some glimmer of knowledge and understanding can be seen emerging from some of the engine's innermost secrets which, even a few years ago, defied reasonable explanation. It is ironic, even amusing, to dwell on the thought that since its inception in 1862, 111 years ago, until the first functional four-stroke cycle engine appeared in 1878, 95 years ago (by different people, incidentally) until now, literally billions of these engines have been built and used satisfactorily, but some of its deeper mysteries may never be solved satisfactorily.
So get your feet wet and your hands dirty: You may be the one to find a secret or two lurking under that blob of cast iron. The four-stroke cycle engine may be a lot of things, but it is NOT dull. NEVER!

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